Mathematically Correct:

Finding the Best Equation for U.S. Math Instruction

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**Introduction**

Math and technology education are becoming increasingly more important in today’s advanced, gadget-driven society. The highest paid jobs are almost unequivocally science based, with engineering and medicine consistently ranking at the top of the charts. Additionally, globalization has made competition for such vocations of high occupational prestige exceedingly stiff. In order to ensure that future generations of American children are productive and viable citizens in the global economy, it is imperative that they are immersed in sound math instruction beginning at the elementary school years. Only once they gain mastery of basic computational skills can they have a chance at excelling at the more abstract levels of problem solving required at the high school and college level and beyond.

**Statement of the Problem**

International mathematics assessments indicate that United States students consistently rank far behind their peers in similarly developed countries. Scores on the National Assessment of Educational Progress, or NAEP, demonstrate that far too few U.S. students are at or above the proficient level in math and science (Epstein & Miller, 2011). New techniques that flout tried and true math teaching methods are a key source of the disparity. Education reformers, representing the education establishment, believe the learning "process" is more important than memorizing core knowledge. They see self-discovery as more important than getting the right answer. Traditionalists, consisting mainly of parent groups and mathematicians, advocate teaching the traditional algorithms. They advocate clear, concrete standards based on actually solving math problems. The destination - getting the right answer - is important to traditionalists.

The textbook that has become the gold standard for reformers is called *Everyday Math*. It is deeply flawed in its approach. It does not teach addition with regrouping and instead uses cumbersome, time-consuming, less efficient, more laborious, non-standard "partial sums" method. It also discourages the practice of standard algorithms for multiplication and division. Here too it incorporates cumbersome, time-consuming, less efficient, more laborious, unduly complicated "extended facts," "partial products," and "lattice" methods. A formal introduction to division algorithms is not included and crutches (e.g., counters, arrays, drawings) in division are never dropped.

**Reform/Constructivist Math Curricula**

*Overview of Reform Math Literature*

Herrera & Owens (2001), note that the most recent movement to revolutionize math teaching in the United States is NCTM Standards-based reform. The reform Standards do not list specific topics to be covered by the end of each grade. Instead, guidelines are provided with examples intended to present a unique conception of math content. One of the benefits of the movement is the push to make concrete connections between mathematics and the real world paramount (Varol & Farran, 2007). There is also more of an emphasis on higher order processing through problem solving, communication, and reasoning. The shift from direct, algorithm-based instruction to Standards-based reform is underpinned by a new emphasis on constructivism and conceptual knowledge over procedural knowledge. In the past, the primary mathematics computation in early school years was based on the pen and paper algorithm (Varol & Farran, 2007). However, modern reformers now realize the importance of mental computation.

Reform mathematics is also known as research-based mathematics because its policies are largely aimed at ensuring that efforts to reform math education are rooted in current and high-quality scientific knowledge about what content students should learn, how they should learn such content, and how they should be assessed (Superfine, Kelso, & Beal, 2010). Whereas many see the reforms as merely a fad, advocates of the movement look for data to back up proposed changes. Fortunately, these changes have been around long enough to be empirically evaluated (see “Field Testing” below).

*Reform Instructional Methods*

Fraivillig, Murphy, & Fuson, (1999) conducted a case study of first grade teacher, Ms. Smith’s, use of the reform text, *Everyday Math*. Her successful strategies included eliciting students’ solution strategies, facilitating their responses, supporting conceptual understanding, and extending mathematical thinking. She encouraged students not to worry about answers per se, but instead to collaborate and explore various problem-solving tactics. This behavior was consistent with the Moyer, Cai, Wang, & Nie, (2011) study that found about twice as many reform lessons as traditional lessons are structured to use group work as a method of instruction.

This is advantageous to students because teachers whose goal it is to foster their students’ interests are more likely to use cooperative activities in math (Durik & Eccles, 2006).

Ma & Singer-Gabella (2011) analyzed routines in reform classes. According to them, a typical teacher script in a reform classroom might be as follows:

I would like for you to solve this problem in as many ways as you can come up

with. I will give you a few minutes to think about it. You can talk to other people if

you like and then we’ll look at some of the methods by which you’ve solved the problem.

A book has 64 pages; you’ve read 37 of those pages, how many pages do you have left to

read? Be sure that for any method you use that you can explain how you did it in terms of

quantity of pages. Come up with as many ways of solving it as you can. (p. 13)

*Reform Theorists/Practitioners*

The standards are based upon the learning theory of Constructivism (Chung, 2004). Constructivism is supported by cognitive theorists, such as Jean Piaget, Jerome Bruner, Zoltan Dienes, and Lev Vygotsky. Notably, Jean Piaget’s intellectual development (sensorimotor, preoperational, concrete operational, and formal operational) and Jerome Bruner’s learning modes (enactive, iconic, and symbolic) provide demonstrations of constructivism in school-age children. Constructivist ideology focuses on processes and the use of manipulatives. Students should be introduced to new concepts in three ways to accomplish representation: action (enactive), visual pictures (iconic), and through the use of words (symbolic). This is meant to help students transition from concrete to abstract levels of understanding.

*Field Testing Reform Math: What the Research Shows at the Elementary Level*

Carrol (1997), found that third grade students across 26 reform curriculum classrooms (as per use of the Everyday Math textbook) scored well above (64 points greater) the state median score on an Illinois State Mathematics Assessment. Moreover, 14 of achievement in the classes containing students who had been immersed in the Everyday Math curriculum since kindergarten was even higher, 75 points above the state score. This suggests a positive longitudinal effect of the curriculum. This is in accordance with other research (Mong & Mong, 2010) indicating that the social validity of an intervention may be affected by the time involved.

A flaw in Carrol’s study is that the author does not indicate what the SES of students in the “traditional classrooms” was in comparison to those in the reform classes. This might indeed be a confounding variable, because students in the traditional classrooms were all from Chicago- a place known to be plagued by poverty and high dropout rates.

Fuson, Carroll, & Drueck (2000), determined that Everyday Math third graders outscored traditional U.S. students on place value and numeration, reasoning, geometry, data, and number-story items. The study is not completely reliable, however. Researchers were not able to match Everyday Math curriculum schools with comparable ones, and therefore chose to use data from existing studies to provide comparisons. Obviously, this is a weaker comparison than using fresh scores and evaluations.

Crawford and Snider (2000), conducted a two-year study conducted in two fourth grade classrooms investigated the effectiveness of two mathematics curricula. Results found that a reform program based on the text *Connecting* ***Math*** *Concepts*, resulted in significantly higher student scores on mathematics tests than the use of a **traditional math** basal textbook. While in this instance, the reform text used did yield higher scores, it is important to note that the specific book in question is not nearly as widespread across elementary schools as its reform counterpart, the ubiquitous text *Everyday Math*.

*Field Testing Reform Curricula in Middle School and Beyond*

There are a couple of studies that suggest reform math might be best implemented in the middle school grades and beyond, when math becomes more abstract and conceptually oriented. Cai, Wang, Moyer, Wang, & Nie (2011) determined that for algebra, the use of reform curriculum contributed significantly to problem-solving growth and students’ ability to represent problem situations. Similarly, in Texas, Vega (2011) found 9th grade ELLs, 9th grade economically disadvantaged students, and 11th grade African American students who were reform taught from 2003-2004 were significantly outperformed those traditionally taught.

**Traditional/Procedural Math Curricula**

*Overview of Traditional Math Curricula*

Traditionalists eschew the reform notion that students can not only construct their own understandings of mathematics, but also actually *reinvent* significant mathematics if given a chance (Frykholm, 2004). Cognitive ability as well as math fluency play an important role in mathematical skills. Understanding the relationship between cognitive abilities and mathematical skills is imperative to teaching effective arithmetic skills (Ramos-Christian & Schleser, 2008).

Traditionalists adhere to the belief that domain-specific mathematical problem-solving skills can be taught by emphasizing worked examples of problem-solution strategies. A worked example provides problem-solving steps and a solution for students. Direct, explicit instruction is vital in all curriculum areas, especially areas that many students find difficult and that are critical to modern societies. Mathematics is such a discipline. Minimal instructional guidance in mathematics leads to minimal learning. In short, traditionalists rely on research indicating that they can teach aspiring mathematicians to be effective problem solvers only by helping them memorize a large store of domain-specific schemas (Sweller, Clark, & Kirschner, 2010).

*Traditional Instructional Methods*

In a traditional framework, mathematical problem-solving skill is acquired through a large number of specific mathematical problem-solving strategies relevant to particular problems. Studying worked examples interleaved with practice solving the type of problem described in the example reduces unnecessary working-memory load that prevents the transfer of knowledge to long-term memory. The improvement in subsequent problem-solving performance after studying worked examples rather than solving problems is known as the worked-example effect (Sweller, Clark, & Kirschner, 2010). The didactic teaching world is highly ritualized and features procedures presented by teachers, with students practicing those procedures alone. For this reason, Son & Senk (2010), report multistep computational problems to be more common in traditional textbooks than in reform ones. Traditional textbooks also excel over reform pedagogies in providing more opportunities to practice number sense skills (Sood & Jitendra, 2007).

*Traditional Theorists/Practitioners*

Sandra Stotsky, Professor of Education Reform at the [University of Arkansas](http://en.wikipedia.org/wiki/University_of_Arkansas), is a staunch traditionalist. She, educated parents, and prominent mathematicians voice objections to the stress on calculator use in the early grades, the over-emphasis on student-developed algorithms at the expense of standard algorithms, and the de-emphasis at the high school level on computation in algebra and proof in Euclidean geometry (Stotsky, 2007). Countries like Singapore and Korea, which consistently outperform American students, also are proponents of traditional, rigorous curricula that focus on procedural knowledge and sound, well-known algorithms.

*Field Testing Traditional Math: What the Research Shows at the Elementary Level*

Three Research studies strongly indicate the efficacy of employing traditional texts. Hook, Bishp, & Hook (2007) established that students in California were shown to make statistically significant gains in math performance over five years of utilizing a text based on the six leading TIMMS math countries in Asia and Europe (which are highly traditionalist oriented). Agodini and Harris (2010) found that across 39 schools first graders using the traditional text, Saxon Math, performed 0.30 SD higher than reform "Investigations" students and 0.24 SD higher than "SFAW" students. Finally, Poncy, McCallum, and Schmitt (2010), utilized an alternating treatments design to compare a traditionalist behavioral intervention, "Cover, Copy, and Compare" (CCC), to an intervention from a reform-oriented resource, "Facts That Last" (FTL). Results demonstrated that CCC led to increases in math-fact fluency, whereas the class-wide response to FTL activities did not differ from the control condition. Two months post-intervention, maintenance data revealed that the fluency increases associated with CCC were sustained.

*Field Testing Traditional Curricula Abroad*

In the Netherlands, Kroesbergen, Van Luit, and Maas (2004) compared the effects of smallgroup constructivistand explicit mathematics instruction in basic multiplication on low-achieving students' performance and motivation. A total of 265 students (aged 8-11 years) from 13 general and 11 special elementary schools for students with learning and/or behavior disorders participated in the study. The experimental groups received 30 minutes of reform or traditional instruction in groups of 5 students twice weekly for 5 months. Pre- and posttests were conducted to compare the effects on students' automaticity, problem-solving, strategy use, and motivation to the performance of a control group who followed the regular curriculum. Results showed that the math performance of students in the traditional instruction condition improved significantly more than that of students in the constructivist condition

**Research Hypotheses**

HR1: 28 4th grade students at O’Neill Elementary School in Central Islip, NY who are immersed in traditional algorithms are expected to yield higher scores on a mathematical assessment gauging two digit multiplication skills than those who are exposed to reform math pedagogies (Everyday Math).

HR2: 28 4th grade students at O’Neill Elementary School in Central Islip, NY who are taught traditional algorithms will achieve higher scores on a mathematical assessment gauging subtraction with regrouping skills than those who are taught primarily through reform texts (Everyday Math).

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Appendix A: Parent Consent form

December 4, 2011

Dear Parent/Guardian,

I am currently a graduate student at Brooklyn College. This semester I am in the process of completing an action research project as one of the requirements for a Research I course. I would like to invite your child to participate in a Comparative Research Study that will be conducted during the school year. Therefore, I am requesting your permission to gather data and incorporate the information in my Master’s Thesis. If you decide to allow your child to participate, he/she may be required to complete questionnaires, demographic surveys, achievement measurements and participate in possible observations. Through this study, I hope to learn about the impact of different math curricula on student performance.

Any information that is obtained in connection with this study and that can be identified with your child will remain confidential and will not be disclosed. The participants will be kept confidential by assuring that all names remain anonymous.

If you have any questions or concerns, please feel free to contact me via email at [kvaz610@gmail.com](mailto:kvaz610@gmail.com). Thank you in advance for your cooperation and support.

Sincerely,  
Katherine Vazquez

I \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ have read and understand the information provided above. I

Parent/Legal Guardian Signature

willingly agree to allow my child to participate in this research project.

Appendix B: Principal Consent Form

December 4, 2011

Dear Principal,

I am presently completing my graduate program at Brooklyn College. This semester I have been asked to conduct an action research project within the classroom. The research project is designed to take a look at the impact of different math curricula on children’s education.  
The survey requires that I choose a few students, and after acquiring parental permission, gather information from them. The chosen children and their parents will be given surveys, questionnaires and tests in addition to the child being observed occasionally. To preserve their privacy, the actual names of the individuals will not be used.

This survey will in no way affect my duties as a teaching professional but rather the information gleaned may prove useful in helping me to understand and relate to the diverse backgrounds from which my students come. I am asking for your consent to conduct the survey within our school. Thank you in advance for your support in this endeavor.

Sincerely,

Katherine Vazquez

I \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ have read and understand the information provided above. I

Principal Signature

willingly agree to allow my school to participate in this research project.

Appendix C: Teacher Consent Form

December 4, 2011

Dear Teachers,

I am presently completing my graduate program at Brooklyn College. This semester I have been asked to conduct an action research project within the classroom. The research project is designed to take a look at the impact of different math curricula on children’s education.  
The survey requires that I choose a few students, and after acquiring parental permission, gather information from them. The chosen children and their parents will be given surveys, questionnaires and tests in addition to the child being observed occasionally. To preserve their privacy, the actual names of the individuals will not be used.

This survey will in no way affect my duties as a teaching professional but rather the information gleaned may prove useful in helping me to understand and relate to the diverse backgrounds from which my students come. I am asking for your consent to conduct the survey within our school. Thank you in advance for your support in this endeavor.

Sincerely,

Katherine Vazquez

I \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ have read and understand the information provided above. I

Teacher Signature

willingly agree to allow my students to participate in this research project.